

PERFORMANCE AND BEHAVIOR
OF FOUR STOREY SCHOOL BUILDING
REINFORCED CONCRETE STRUCTURE
UNDER ACHEH AND BUKIT TINGGI
EARTHQUAKE LOADING

NURNAJAT NADIRA
BINTI ABDUL RAHMAN

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG



SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering (Hons)

(Supervisor's Signature)

Full Name : IR. DR. SAFFUAN BIN WAN AHMAD

Position : SENIOR LECTURER

Date :



STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : NURNAJAT NADIRA BINTI ABDUL RAHMAN

ID Number : AA 13286

Date :

PERFORMANCE AND BEHAVIOR OF FOUR STOREY SCHOOL BUILDING
REINFORCED CONCRETE STRUCTURE UNDER
ACHEH AND BUKIT TINGGI EARTHQUAKE LOADING

NURNAJAT NADIRA BINTI ABDUL RAHMAN

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2017

**In dedication to my family,
For making me who I am,
And my friends for supporting me all the wat**

ACKNOWLEDGEMENTS

First of all I would like to be grateful to Allah S.W.T by reason of giving me chance to finish my final year project in fixed period and giving me good health along this period. Without His power, I was unable to finish my report in expected time.

I wish to express my sincere thanks to Universiti Malaysia Pahang (UMP) for giving me an opportunity to finish my Final Year Project this semester. I also would like to express my appreciation to my supervisor, Ir. Dr. Saffuan bin Wan Ahmad for his guidance, support, idea and encouragement in making this research complete in a given time. Without his support and help throughout the process, I would face difficulties in completing this research.

I would also like to show my appreciation to my parents for giving me moral support and all who, directly or indirectly, have lent their helping hand in this venture. With their cooperation's makes my final year project become easier and full of fun. My special thanks also to my research friend, for their cooperation and assistance in helping me in order to finish the report. Not to forget, who has support me academically and emotionally in the month I spent for this project. Last but not least, thank you Dr. Nurul Nadrah Aqilah binti Tukimat as the coordinator of final year project whose guidance if this research was deeply appreciated.

TABLE OF CONTENT

| | |
|------------------------------------|-------------|
| TITLE PAGE | |
| ACKNOWLEDGEMENTS | iii |
| ABSTRACT | iv |
| ABSTRAK | v |
| TABLE OF CONTENT | vi |
| LIST OF TABLES | ix |
| LIST OF FIGURES | x |
| LIST OF SYMBOLS | xiii |
| LIST OF ABBREVIATIONS | xiv |
| CHAPTER 1 INTRODUCTION | 1 |
| 1.1 BACKGROUND OF STUDY | 1 |
| 1.2 PROBLEM STATEMENT | 2 |
| 1.3 RESEARCH OBJECTIVE | 3 |
| 1.4 SCOPE OF STUDY | 3 |
| 1.5 RESEARCH SIGNIFICANCE | 4 |
| CHAPTER 2 LITERATURE REVIEW | 5 |
| 2.1 EARTHQUAKE | 5 |
| 2.2 SEISMIC WAVE | 7 |
| 2.2.1 Body Waves | 8 |
| 2.2.2 Surface Waves | 10 |
| 2.2.3 Rayleigh Waves | 11 |

| | | |
|---|--|-----------|
| 2.3 | MEASURING EARTHQUAKE | 12 |
| 2.3.1 | Seismographs | 12 |
| 2.4 | EARTHQUAKE MAGNITUDE | 14 |
| 2.5 | REINFORCED CONCRETE FOUR STOREY BUILDING STRUCTURE | 15 |
| 2.6 | SAP2000 PROGRAM | 16 |
| CHAPTER 3 METHODOLOGY | | 18 |
| 3.1 | INTRODUCTION | 18 |
| 3.1.1 | Research Planning | 19 |
| 3.2 | LITERATURE REVIEW | 20 |
| 3.3 | INFORMATION AND DATA COLLECTION | 20 |
| 3.3.1 | Reinforced Concrete School Building Structure | 20 |
| 3.4 | SAP2000 PROGRAM | 21 |
| 3.4.1 | Modelling | 22 |
| 3.4.2 | Steps in SAP2000 Software | 23 |
| CHAPTER 4 RESULTS AND DISCUSSION | | 39 |
| 4.1 | INTRODUCTION | 39 |
| 4.2 | CHARACTERISTICS OF FOUR STOREY BUILDING | 39 |
| 4.3 | ANALYSIS OF FOUR STOREY CONCRETE SCHOOL BUILDING | 40 |
| 4.3.1 | Free Vibration Analysis (Modal Analysis) | 40 |
| 4.3.2 | Dead Load and Live Load | 44 |
| 4.3.3 | Dead Load and Live Load, Wind Load and Earthquake Load (Acheh) | 47 |
| 4.3.4 | Dead Load and Live Load, Wind Load and Earthquake Load (Bkt Tinggi) | 49 |
| 4.3.5 | Comparison of Structure Capacity and Resistance | 51 |

| | | |
|-------|--|-----------|
| 4.4 | VIRTUALWORK DIAGRAM | 53 |
| 4.5 | TIME HISTORY ANALYSIS | 55 |
| 4.6 | RESPONSE SPECTRUM ANALYSIS (RSA) | 57 |
| 4.6.1 | Time Period | 58 |
| 4.6.2 | Frequency | 63 |
| 4.7 | SUMMARY OF THE ANALYSIS | 69 |
| 4.7.1 | Time Period | 69 |
| 4.7.2 | Result of Load Combination | 70 |
| 4.7.3 | Time History | 71 |
| 4.7.4 | Response Spectrum Analysis (RSA) | 72 |
| | CHAPTER 5 CONCLUSION AND RECOMMENDATIONS | 73 |
| 5.1 | CONCLUSION | 73 |
| 5.1.1 | Vulnerability of Existing Building Under an Earthquake Loading | 73 |
| 5.1.2 | The Force Produce in the RC Building under Aceh and Bukit Tinggi Earthquake Load | 74 |
| 5.1.3 | Dynamic Characteristics of RC building under Different Types of Loading | 74 |
| 5.2 | RECOMMENDATIONS | 74 |
| | REFERENCES | 76 |
| | APPENDIX A1 CALCULATION OF MAXIMUM RESISTANCE FOR BEAM | 77 |
| | APPENDIX A2 CALCULATION OF MAXIMUM RESISTANCE FOR COLUMN | 79 |

LIST OF TABLES

| Table No. | Title | Page |
|------------------|---|-------------|
| Table 2.1 | Earthquake severity-Ritcher scale | 14 |
| Table 4.1 | Tabulated period and frequency of modal analysis | 43 |
| Table 4.2 | Comparison of RC structure torsion maximum resistance for Beam 172 | 52 |
| Table 4.3 | Comparison of RC structure shear maximum resistance for Beam 172 | 52 |
| Table 4.4 | Comparison of RC structure torsion maximum resistance for Column 104 | 52 |
| Table 4.5 | Comparison of RC structure shear maximum resistance for Column 104 | 53 |
| Table 4.6 | Peak response spectrum for Acheh excitation in x-direction (Time period) | 60 |
| Table 4.7 | Peak response spectrum for Acheh excitation in y direction (Time Period) | 60 |
| Table 4.8 | Peak response spectrum for Bukit Tinggi excitation in x direction (Time Period) | 63 |
| Table 4.9 | Peak response spectrum for Bukit Tinggi excitation in y direction (Time Period) | 63 |
| Table 4.10 | Peak response spectrum for Acheh excitation in x direction (Frequency) | 65 |
| Table 4.11 | Peak response spectrum for Acheh excitation in y direction (Frequency) | 66 |
| Table 4.12 | Peak response spectrum for Bukit Tinggi excitation in x direction (Frequency) | 68 |
| Table 4.13 | Peak response spectrum for Bukit Tinggi excitation in y direction (Frequency) | 68 |
| Table 4.14 | Analysis of concrete building design | 69 |
| Table 4.15 | Maximum result of beam 172 subjected under different load combination | 70 |
| Table 4.16 | Maximum displacement and acceleration of 0% damping under different excitation | 71 |

LIST OF FIGURES

| Figure No. | Title | Page |
|-------------------|---|-------------|
| Figure 1.1 | Earthquake event | 1 |
| Figure 2.1 | Crustal Stress | 6 |
| Figure 2.2 | Location of earthquake surface | 6 |
| Figure 2.3 | Model cube of P-waves | 9 |
| Figure 2.4 | Model cube of S-waves | 10 |
| Figure 2.5 | Model cube of Love waves | 11 |
| Figure 2.6 | Model cube of Rayleigh | 12 |
| Figure 2.7 | A seismograph used to measure ground motion | 13 |
| Figure 2.8 | SAP2000 Program Version | 17 |
| Figure 3.1 | Flowchart of research planning | 19 |
| Figure 3.2 | AutoCAD Drawing of front view | 21 |
| Figure 3.3 | AutoCAD Drawing of top floor view | 21 |
| Figure 3.4 | Modelling SAP2000 | 22 |
| Figure 3.5 | Define grid of system data | 24 |
| Figure 3.6 | Geometry value of the structure | 24 |
| Figure 3.7 | Grid Data System | 25 |
| Figure 3.8 | Restraints at the base condition | 25 |
| Figure 3.9 | Frame section definition properties | 26 |
| Figure 3.10 | Add frame section property | 26 |
| Figure 3.11 | Quick material definition | 26 |
| Figure 3.12 | Section name and size of section | 27 |
| Figure 3.13 | Shell section data | 28 |
| Figure 3.14 | Frame properties for column | 28 |
| Figure 3.15 | Assign of area section of slab | 29 |
| Figure 3.16 | Structure layout produced in SAP2000 | 29 |
| Figure 3.17 | Define time history function | 30 |
| Figure 3.18 | Data taken from file | 30 |
| Figure 3.19 | Raw Data of earthquake from MMD | 31 |
| Figure 3.20 | Time history function of Acheh dan Bukit Tinggi | 31 |
| Figure 3.21 | Response Spectrum function | 32 |
| Figure 3.22 | Load patterns | 32 |
| Figure 3.23 | Define load cases | 33 |
| Figure 3.24 | Response Spectrum load case | 33 |
| Figure 3.25 | Time History load case | 34 |
| Figure 3.26 | Completed load case for analysis | 34 |
| Figure 3.27 | Load combination | 35 |
| Figure 3.28 | Running the analysis | 35 |
| Figure 3.29 | Analysing model | 36 |
| Figure 3.30 | Structure of the ran analysis | 36 |
| Figure 3.31 | Member force diagram | 37 |
| Figure 3.32 | Member force mode | 37 |
| Figure 3.33 | Force of displacement | 38 |
| Figure 4.1 | Modal analysis : Mode shape 1 and 2 | 41 |
| Figure 4.2 | Modal analysis : Mode shape 3 and 4 | 41 |
| Figure 4.3 | Modal analysis : Mode shape 5 and 6 | 41 |
| Figure 4.4 | Modal analysis : Mode shape 7 and 8 | 42 |

| | | |
|-------------|---|----|
| Figure 4.5 | Modal analysis : Mode shape 9 and 10 | 42 |
| Figure 4.6 | Modal analysis : Mode shape 11 and 12 | 42 |
| Figure 4.7 | Result from analysis of modal | 43 |
| Figure 4.8 | Critical beam used for analysis | 45 |
| Figure 4.9 | Selected critical column use for analysis | 45 |
| Figure 4.10 | Result of shear moment and deflection beam 172 | 46 |
| Figure 4.11 | Result of axial force and torsion for beam 172 | 46 |
| Figure 4.12 | Result of stress for beam 172 | 46 |
| Figure 4.13 | Result of shear, moment and deflection for column 104 | 47 |
| Figure 4.14 | Result of axial force and torsion for column 104 | 47 |
| Figure 4.15 | Result of stress for column 104 | 47 |
| Figure 4.16 | Result of shear and moment for beam 172 | 48 |
| Figure 4.17 | Result of axial force and torsion for beam 172 | 48 |
| Figure 4.18 | Result of stress for beam 172 | 48 |
| Figure 4.19 | Result of shear, moment and deflection for column 104 | 49 |
| Figure 4.20 | Result of axial force and torsion for column 104 | 49 |
| Figure 4.21 | Result of stress for column 104 | 49 |
| Figure 4.22 | Result of shear and moment for beam 172 | 50 |
| Figure 4.23 | Result of axial force and torsion for beam 172 | 50 |
| Figure 4.24 | Result of stress for beam 172 | 50 |
| Figure 4.25 | Result of shear, moment and deflection for column 104 | 51 |
| Figure 4.26 | Result of axial force and torsion for column 104 | 51 |
| Figure 4.27 | Result of stress for column 104 | 51 |
| Figure 4.28 | Virtual work diagram | 54 |
| Figure 4.29 | Virtual work diagram | 54 |
| Figure 4.30 | Virtual work diagram | 54 |
| Figure 4.31 | Virtual work diagram | 54 |
| Figure 4.32 | Virtual work diagram | 54 |
| Figure 4.33 | Virtual work diagram | 54 |
| Figure 4.34 | Maximum joint displacement in x direction | 55 |
| Figure 4.35 | Maximum joint displacement in y direction | 56 |
| Figure 4.36 | Maximum joint acceleration in x direction | 56 |
| Figure 4.37 | Maximum joint acceleration in y direction | 57 |
| Figure 4.38 | Spectral displacement in x direction | 58 |
| Figure 4.39 | Spectral displacement in y direction | 58 |
| Figure 4.40 | Spectral velocities in x direction | 59 |
| Figure 4.41 | Spectral velocities in y direction | 59 |
| Figure 4.42 | Pseudo spectral velocities in x direction | 59 |
| Figure 4.43 | Pseudo spectral velocities in y direction | 59 |
| Figure 4.44 | Spectral acceleration in x direction | 59 |
| Figure 4.45 | Spectral acceleration in y direction | 59 |
| Figure 4.46 | Pseudo spectral acceleration in x direction | 60 |
| Figure 4.47 | Pseudo spectral acceleration in y direction | 60 |
| Figure 4.48 | Spectral displacement in x direction | 61 |
| Figure 4.49 | Spectral displacement in y direction | 61 |
| Figure 4.50 | Spectral velocities in x direction | 61 |
| Figure 4.51 | Spectral velocities in y direction | 61 |
| Figure 4.52 | Pseudo spectral velocities in x direction | 62 |
| Figure 4.53 | Pseudo spectral velocities in y direction | 62 |
| Figure 4.54 | Spectral acceleration in x direction | 62 |

| | | |
|-------------|---|----|
| Figure 4.55 | Spectral acceleration in y direction | 62 |
| Figure 4.56 | Pseudo spectral acceleration in x direction | 62 |
| Figure 4.57 | Pseudo spectral acceleration in y direction | 62 |
| Figure 4.58 | Spectral displacement in x direction | 64 |
| Figure 4.59 | Spectral displacement in y direction | 64 |
| Figure 4.60 | Spectral velocities in x direction | 64 |
| Figure 4.61 | Spectral velocities in y direction | 64 |
| Figure 4.62 | Pseudo spectral velocities in x direction | 64 |
| Figure 4.63 | Pseudo spectral velocities in y direction | 64 |
| Figure 4.64 | Spectral acceleration in x direction | 65 |
| Figure 4.65 | Spectral acceleration in y direction | 65 |
| Figure 4.66 | Pseudo spectral acceleration in x direction | 65 |
| Figure 4.67 | Pseudo spectral acceleration in y direction | 65 |
| Figure 4.68 | Spectral displacement in x direction | 66 |
| Figure 4.69 | Spectral displacement in y direction | 66 |
| Figure 4.70 | Spectral velocities in x direction | 67 |
| Figure 4.71 | Spectral velocities in y direction | 67 |
| Figure 4.72 | Pseudo spectral velocities in x direction | 67 |
| Figure 4.73 | Pseudo spectral velocities in y direction | 67 |
| Figure 4.74 | Spectral acceleration in x direction | 67 |
| Figure 4.75 | Spectral acceleration in y direction | 67 |
| Figure 4.76 | Pseudo spectral acceleration in x direction | 68 |
| Figure 4.77 | Pseudo spectral acceleration in y direction | 68 |

LIST OF SYMBOLS

| | |
|-----|---------------------|
| U1 | Move in x-direction |
| U2 | Move in y-direction |
| d | Depth |
| u | Perimeter |
| Z | Lever arm |
| Ø | Diameter |
| θ | Angle |
| fck | Concrete strength |

LIST OF ABBREVIATIONS

| | |
|------------|--------------------------------------|
| 2D | Two dimensional |
| 3D | Three dimensional |
| RC | Reinforced Concrete |
| DL | Dead Load |
| LL | Live Load |
| WL | Wind Load |
| BKT TINGGI | Bukit Tinggi |
| RSA | Response Spectrum Analysis |
| SAP | Structural Analysis & Design Program |